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AFPDS Bagged Propellant Fire Suppression Evaluations

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14. ABSTRACT
The purpose of the evaluations was to confirm the Advanced Fire Protection Deluge System (AFPDS) is suitable for high-speed fire suppression of bagged propellant in a Weapons Surveillance, Inspection and Quality Control function. No previous AFPDS evaluations were conducted with bagged propellant. The AFPDS detects fires and rapidly dispenses water to the burning material surface providing control and extinguishment. A mock up of inspection operations was assembled at AFRL/MLQD Test Range II. An existing 4-foot wide table was positioned 35 inches below an AFPDS. Two types of bagged propellant were obtained from the U.S. Army Operations Support Command Safety Office to burn in these evaluations. Based upon the results, recommendations were made for constructing a table for propellant inspection operations.

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EXECUTIVE SUMMARY

BACKGROUND

The research and development evaluations conducted and documented in this report were accomplished for the U.S. Army. The purpose was to confirm the Advanced Fire Protection Deluge System (AFPDS) is suitable for high-speed fire suppression of bagged propellant in a Weapons Surveillance, Inspection and Quality Control function. The AFPDS detects fires and rapidly dispenses water to the burning material surface providing control and extinguishment. No previous AFPDS evaluations were conducted with bagged propellant.

APPROACH

A mock up of the inspection operations was assembled at AFRL/MLQD Test Range II at Tyndall AFB, FL. An existing 4-foot wide table was positioned 35 inches below an AFPDS. Two types of bagged propellant (M3 and M4) were obtained from the U.S. Army Operations Support Command Safety Office to burn in these evaluations. Seven propellant charges were provided to AFRL/MLQD and six tests were originally planned, two unsuppressed and four suppressed. However, due to results of initial evaluations, changes were made and the end result was six suppressed and one unsuppressed evaluations.

CONCLUSIONS & RECOMMENDATIONS

In each of the first four M3 propellant fires the AFPDS prevented propagation of the fire to the outside bags; however, it did not completely extinguish the fires. It was obvious from the video that the AFPDS better controlled the initial fires in Test 2 and Test 4 when the propellant was placed closer to the centerline underneath the sphere. After modifying the table with a four-inch rim, the last M3 fire, in Test 6, was extinguished 25 ms after flame detection. The propellant bag sustained more damage in Test 6 than in other evaluations, however, the fast and thorough extinguishment of the propellant showed a greater level of protection for workers in the area.

The four-inch rim that was added to the table aided in containing the water and propellant together and kept the propellant bag within the protection area provided by the water spray. More propellant grains were wet by the water spray after this modification which prevented their ignition and burning.

The M4 propellant used in Test 5 was easily extinguished by the AFPDS. Figure 4 shows that the M4 propellant grains were larger than the M3 grains. In our limited evaluations the M4 appeared to propagate slower when burning. There were no remains of the M4 after an unsuppressed test.

It is recommended to build or purchase a table for the propellant inspection operations when using the AFPDS mounted to a wall. This table width should be minimized to allow it to fit within the cone of protection provided by the AFPDS suppression system. The distance from the propellant to the sphere extinguisher should also be minimized.   A 30-inch by 50-inch table with walls on two or three sides and a four-inch rim on the remaining sides is recommended. However, the table should be specified consistent with inspection operations in the facility.

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BACKGROUND

The research and development evaluations conducted and documented in this report were accomplished for the U.S. Army. The purpose was to confirm the Advanced Fire Protection Deluge System (AFPDS) is suitable for high-speed fire suppression of bagged propellant in a Weapons Surveillance, Inspection and Quality Control function. In several years of testing, development and field evaluation, the AFPDS has been proven to be an effective fire protection tool against burning pyrotechnics, propellants and HE materials. The AFPDS detects fires and rapidly dispenses water to the burning material surface providing control and extinguishment. Most of the previous AFPDS evaluations were conducted with non-contained munitions materials and no previous tests were conducted with bagged propellant.

Many ammunition inspection operations prefer to use a 4-foot by 8-foot table to inspect munitions. This table would be protected by an AFPDS with a 10L sphere and two solenoid activated nozzles. The propellant being inspected would be located approximately 36 inches below and 30 inches out from the center of the sphere nozzle.

APPROACH

A mock up of the inspection operations was assembled at AFRL/MLQD Test Range II at Tyndall AFB, FL. An existing 4-foot wide table was positioned 35 inches below an AFPDS. Heat flux and temperature sensors were positioned at the front of the table and on the floor. Two types of bagged propellant (M3 and M4) were obtained from the U.S. Army Operations Support Command Safety Office to burn in these evaluations.

Seven propellant charges were provided to AFRL/MLQD and six evaluations were originally planned, two unsuppressed and four suppressed. During the course of testing these plans changed due to results of initial evaluations. Initial results showed that the system would not perform as operators had hoped. Modifications from the original plan were made to the placement of the propellant and to the table. The remaining tests were conducted to show that with slight modifications to the table and the propellant placement, the area around the fire could be effectively protected. The end result was six suppressed and one unsuppressed evaluations.

SETUP & TESTING

All evaluations were conducted in the NATO facility at AFRL/MLQ Test Range II. This test facility was set-up with an AFPDS suppression system. The suppression system consisted of one 10L sphere extinguisher, two 1¼-inch Pyrotech solenoid nozzles and one Fire Sentry high-speed flame detector. The bottom of the sphere nozzle was located 35 inches above the table and the solenoid nozzles were 42 inches above the table. The flame detector was mounted 12 inches behind the sphere nozzle and 40 inches above the table.

Figure 1: Suppression System and Table with M3 Propellant

An existing table was placed under the suppression system and the propellant was placed on this table. The table top was ¼-inch steel with dimensions 52 inches wide and 48 inches deep. The table had three 30-inch high, ¼-inch steel walls. Initial plans were to conduct two suppressed fires on the table, then to remove the left and right walls and continue with the remaining fires. However, the initial fires were not extinguished immediately. The propellant bags were forced off of the table by the water spray and continued to burn or reignited after they were outside of the protection of the water spray. The decision was made to keep the walls in place for the remaining evaluations and to add a four-inch rim to the table edge to contain the propellant and the water.

The propellant used was M3 (5.5 pound bags) and M4 (13 pound bags). Two electric matches were used to initiate the M3 propellant. The M4 propellant was initiated with an electric match and a small amount of smokeless powder (<10 g). The propellant grains inside the M3 and M4 bags were different sizes (see Figure 4). The smaller grain M3 seemed to have a faster burning rate based on the few fires conducted in this series.

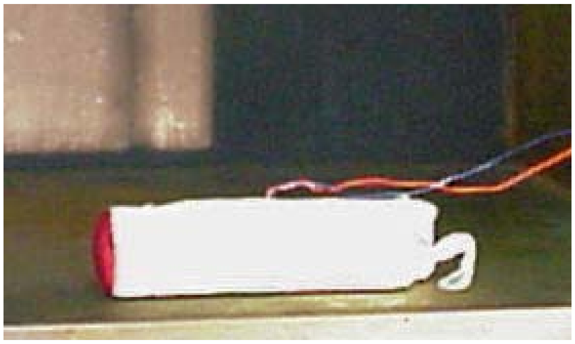

Figure 2: M3 Propellant (5.5 lbs)

Figure 3: M4 Propellant (13 lbs)

Figure 4: M4 Propellant grain (left); M3 Propellant grain (right)

A data acquisition system was set-up to record temperature, heat flux and detector response times. Temperatures and heat flux were measured with K-type thermocouples and Thermogage™ heat flux transducers at five locations where a workers hand and face may be during a fire. These sensors were located on stands seen in Figure 1 on the left and right front of the table. Temperatures were also measured at three locations on the floor in front of the table. Regular speed video of all tests was recorded from three angles and high-speed video was recorded from the front side of the table.

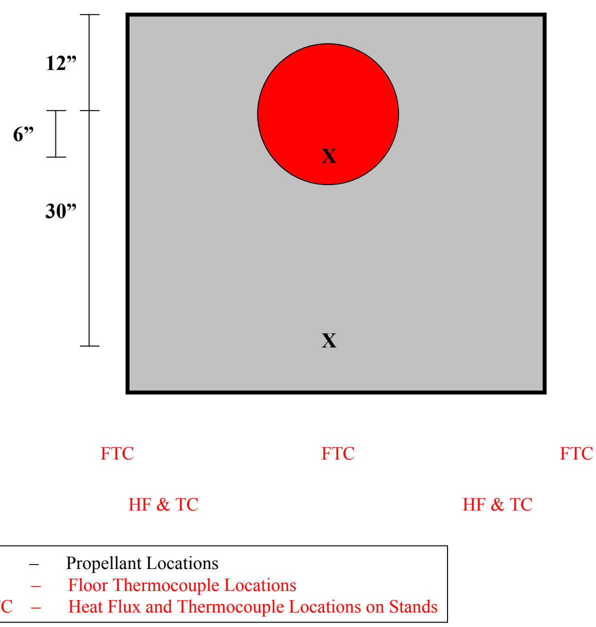

Figure 5: Test Setup (Top View)

RESULTS

A typical high-speed deluge system discharge has the following 10 events as listed in the AFPDS Phase II Report[1, 2].

1. Event Initiation - The button is pushed to ignite the electric match or to begin heating the bridgewire and start the test.
2. Deflagration begins.
3. Detectable Event - The first indication of a visible fire ball (deflagration), generated by the ignited material, as viewed on the high-speed camera that should be "seen" by a detector. (Note: There were times during these Phase II tests that a detector detected the event before the detectable event (i.e. before the flame was visible). This is denoted as a negative (-) detection time in the following charts.)
4. The flame grows to a size where the radiation released is sufficient for detector reaction.
5. Detector Alarm - The fire detector sends a fire alarm signal to the control panel. The radiation required for detection varies with each detector's sensitivity and affects detection time.
6. Controller Out - The control panel, after receiving the signal from the flame detector, sends a signal to the water discharge devices.
7. The squib and solenoid valves receive the signal from the control panel and begin to react.
8. Water Discharge - Water exits the nozzle.
9. Water from the nozzle reaches the burning material.
10. Fire Suppression (extinguishment) - The first indication on the high speed camera of no fireball remaining.

Table 1 shows a summary of results. All times are measured from the detectable event. Detailed information on each test is listed below.

TABLE 1: Test Results

TEST #	MATERIAL	TEST APPARATUS	Off-Axis Distance	FLAME DETECTION	CONTAINMENT	EXTINGUISHMENT
1	M3	Table	30 in.	34ms	DN	DN
2	M3	Table	6 inches	23ms	39ms*	DN
3	M3	Table	30 in.	22ms	DN	DN
4	M3	Table	6 inches	24ms	47ms*	DN
5	M4	Table with Rim	6 inches	21ms	41ms	50ms
6	M3	Table with Rim	6 inches	23ms	44ms	48ms
7	M4	Table with Rim	6 inches	25ms	No Suppression	No Suppression

DN – Did Not – The fire continued to burn on the floor.
* - Temporarily contained the fire. The fire continued to burn on the floor.

Test 1

One bag of M3 propellant was located on the table, 35 inches below and 30 inches in front of the sphere nozzle (See Figures 1 and 6). The M3 bag consists of five charges, three small charges in the middle and two large charges on the outside. A single electric match failed to ignite the material; so two electric matches were connected in parallel. After ignition, the fire was detected 34 ms after the detectable event. Water discharged from the sphere 36 ms after the detectable event. Due to the location and size of the fireball, the fire was never contained, and although the water spray impacted the propellant, the density was not great enough to extinguish the fire. The spray did prevent the fire propagation to the two outside propellant charges that remained intact after the test. The propellant was pushed off the table and continued to burn on the floor for six seconds. Afterwards the propellant grains from the three inside charges were scattered across the floor in front of the table.

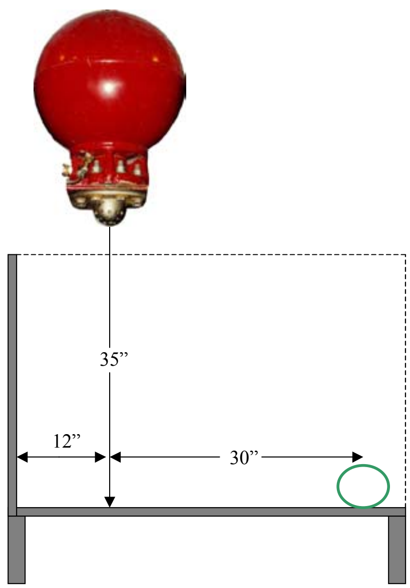

Figure 6: Location of AFPDS and M3 Propellant (Side View)

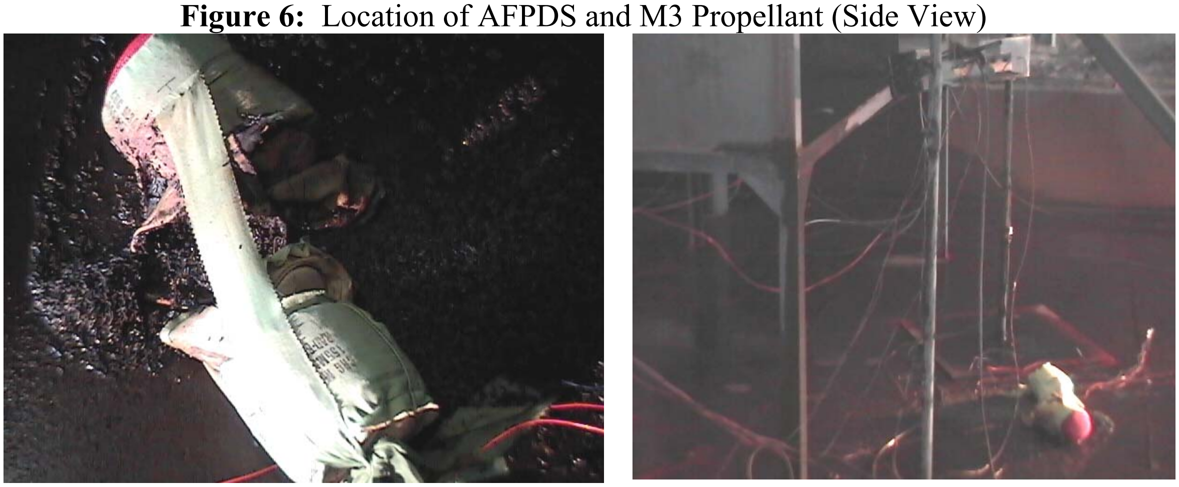

Figure 7: Test 1 Results

Test 2

One bag of M3 propellant was located on the table, 35 inches below and six inches in front of the sphere nozzle (See Figures 8 and 9). The bag was moved closer for this test to determine the effect on suppression. Two electric matches were used to ignite the material. After ignition, the fire was detected 23 ms after the detectable event. Water discharged from the sphere 25 ms after the detectable event. The initial fireball was contained almost immediately and suppressed 24 ms after flame detection. However, at some point the material that washed off the table reignited on the floor and went out 1.5 seconds after ignition (Evidence of this flame was recorded on video and measured by thermocouples on the floor). Most of the propellant residue remained on the table including the two outside propellant charges that remained intact. The propellant remaining after the test was approximately equivalent to that in Test 1 with a small portion on the floor.

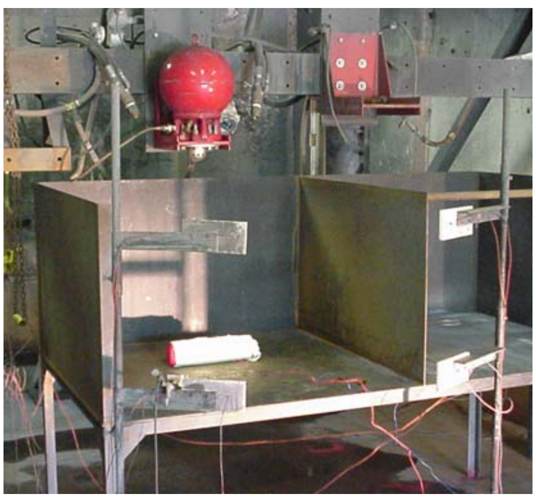

Figure 8: Suppression System and Table with M3 Propellant

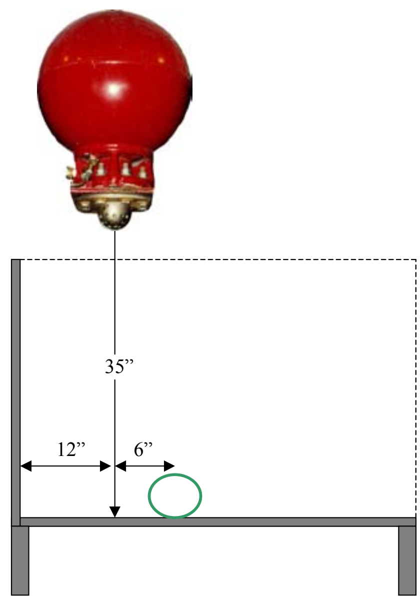

Figure 9: Location of AFPDS and M3 Propellant (Side View)

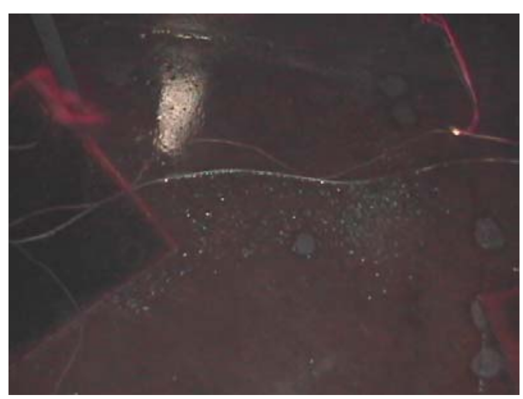

Figure 8: Test 2 Results

Test 3

This was a repeat of Test 1. One bag of M3 propellant was located on the table, 35 inches below and 30 inches in front of the sphere nozzle (See Figures 1 and 6). A single electric match (different manufacturer than test 1) was used to ignite the material. After ignition, the fire was detected 22 ms after the detectable event. Water discharged from the sphere 24 ms after the detectable event. The fire appeared to be suppressed 60 ms after detection, however the flame came back 213 ms after detection with a fireball over seven feet high. Again, the low density of water spray contributed to the fireball coming back with such intensity. The fire went out eight seconds after detection. Afterwards, propellant grains from the three inside charges and one outside charge were scattered across the floor in front of the table. The remaining outside charge remained intact.

Figure 11: Test 3 Results

Test 4

This was a repeat of Test 2. One bag of M3 propellant was located on the table, 35 inches below and six inches in front of the sphere nozzle (See Figures 7 and 8). A single electric match was used to ignite the material. After ignition, the fire was detected 24 ms after the detectable event. The fire was suppressed on the table 35 ms after detection, however as in Test 2, the fire reignited on the floor. Unlike Test 2, all of the propellant was washed off the table. The fire went out five seconds after detection. Afterwards, propellant grains from the three inside charges were scattered across the floor in front of the table. The two outside charges remained intact.

 

Figure 12: Test 4 Results

After Test 4, the table was modified with a four-inch tall, ¼-inch steel rim. The rim was installed to contain the propellant and prevent combustion of propellant that is washed onto the floor. Also, the propellant was placed as shown in Figure 13 for the remaining evaluations. This modification worked so well that it is recommended for all applications involving munitions inspections on tables.

 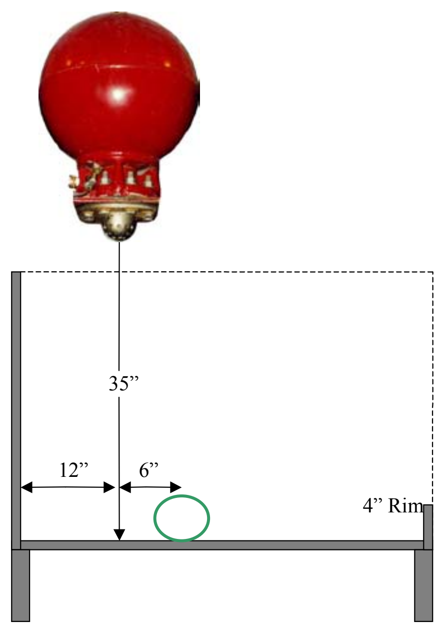

Figure 13: Tests 5-7 Setup

Test 5

One bag of M4 propellant (13 lbs) was located on the table, 35 inches below and six inches in front of the sphere nozzle (See Figure 13). After a single electric match did not ignite the propellant, 10g of smokeless powder was added to the match to ignite the

material. After ignition, the fire was detected 21 ms after the detectable event. The fire was suppressed on the table 29 ms after detection. The propellant bag remained intact and the four-inch rim on the table prevented the bag from washing off the table. The propellant in the M4 bag is larger than the M3 bag and may have made this fire easier to extinguish.

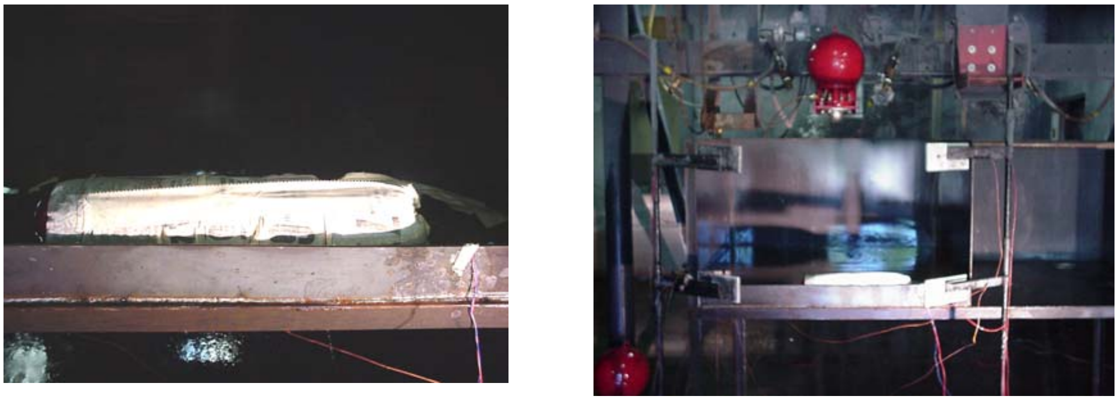

Figure 14: Test 5 Results

Test 6

One bag of M3 propellant (5.5 lbs) was located on the table, 35 inches below and six inches in front of the sphere nozzle (See Figure 13). A single electric match was used to ignite the propellant. After ignition, the fire was detected 23 ms after the detectable event and suppressed 25 ms after detection. The four-inch rim prevented the propellant bag and most of the grains from washing off the table. A few grains did end up on the floor as seen in Figure 15. The propellant bag sustained more damage than in other evaluations. Propellant grains from the three inside charges and one outside charge were scattered around the table. The other outside charge remained intact.

There was more smoke generated in this test than in other tests. It appears from the video that the material in the bag smoldered after extinguishment generating a significant amount of smoke.

Figure 15: Test 6 Results

Test 7

One unsuppressed burn of M4 propellant (13 lbs) was conducted to determine the effect of the suppression system. The propellant was located on the table, 35 inches below and six inches in front of the sphere nozzle (See Figure 13). An electric match with 10g of smokeless powder was used to ignite the material. The material burned completely.

Figure 16: Test 7 Results

CONCLUSIONS & RECOMMENDATIONS

In each of the first four M3 propellant fires the AFPDS prevented propagation of the fire to the outside bags; however, it did not completely extinguish the fires. In each evaluation material was washed onto the floor and continued to burn on the floor where the water spray could not reach. It was obvious from the video that the AFPDS better controlled the initial fires in Test 2 and Test 4 when the propellant was placed closer to the centerline underneath the sphere.

After modifying the table with a four-inch rim, the last M3 fire, in Test 6, was extinguished 25 ms after flame detection. The propellant bag sustained more damage in Test 6 than in other evaluations, however, the fast and thorough extinguishment of the propellant showed a greater level of protection for workers in the area.

The four-inch rim that was added to the table aided in containing the water and propellant together and kept the propellant bag within the protection area provided by the water spray. More propellant grains were wet by the water spray after this modification which prevented their ignition and burning.

The M4 propellant used in Test 5 was easily extinguished by the AFPDS. Figure 4 shows that the M4 propellant grains were larger than the M3 grains. In the limited fires, the M4 appeared to propagate slower when burning. This slower propagation should make the material easier to extinguish. There were no remains of the M4 after the unsuppressed fire.

In all suppressed fires, propellant grains were blown around and off of the table. Eye protection is critical for workers in the area around the deluge system.

Temperature and heat flux measurements did not show significant changes in temperature or heat flux except in cases where the burning material was pushed toward that sensor. Sensors on the floor where the water spray did not reach showed the highest temperatures. The water spray kept temperatures down on the table. Temperatures did increase significantly in the unsuppressed fire.

It is recommended to build or purchase a table for the propellant inspection operations when using the AFPDS mounted to a wall. This table width should be minimized to allow it to fit within the cone of protection provided by the AFPDS suppression system. The distance from the propellant to the sphere extinguisher should also be minimized. A 30-inch by 50-inch table with walls on two or three sides and a four-inch rim on the remaining sides is recommended. However, the table should be specified consistent with inspection operations in the facility.

REFERENCES

1. Wells, S.P., Carr, V., Cozart, K.S. Advanced Fire Protection Deluge System (AFPDS) Phase I Report. Air Force Research Laboratory, Fire Protection Group, Tyndall Air Force Base, FL 32403, April 2000.

2. Gagnon, Robert N. Ultra High Speed Suppression Systems for Explosive Hazards. Fire Protection Handbook, Eighteenth Edition, National Fire Protection Association, 1997.

3. NFPA 15. Water Spray Fixed Systems for Fire Protection. National Fire Codes. National Fire Protection Association, Inc. Quincy, MA. 1996.

4. DOD Ammunition and Explosives Safety Standards, DOD 6055.9-STD, July 1999.

5. AMC Safety Manual, AMCR 385-100, 26 Sep 1995.

6. Loyd, Robert A., Evaluation of Ultra-High-Speed Fire Protection Systems Presently in Service at Army Ammunition Plants, U.S. Army Armament, Munitions and Chemical Command Safety Office, Department of Defense Explosives Safety Seminar, August 1994.

7. Military Handbook – Fire Protection for Facilities Engineering, Design, and Construction, MIL-HDBK-1008C, 15 January 1994.